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Original Article

Spatially Explicit Analysis of Contributions of a Regional Conservation Strategy Toward Sustaining Northern Goshawk Habitat

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ABSTRACT Setting aside habitat is a common strategy to maintain viable wildlife populations, but underlying assumptions or effectiveness are rarely evaluated. The Tongass National Forest prioritized habitat management for sensitive species in Southeast Alaska's rainforest, and standards and guidelines were established for northern goshawks (*Accipiter gentilis*). I used guidelines from other portions of its range and data from Southeast Alaska, USA, to evaluate the conservation strategy. I used published data and nests from this study to define choice habitats; published juvenile movements and female use areas were used to estimate an "average" post-fledging area and female breeding range, respectively. I used nest-tree locations ($n = 136$) to delineate corresponding virtual post-fledging areas and female home ranges, within which I calculated acreage of 4 cover-type and 4 land-use categories. About 30% of nests had >51% of post-fledging areas in choice habitat; 60% of nests had >51% in unsecure (unprotected from development) land-use designations, whereas 16% had >51% in a protected old-growth designation. The female range was similar to post-fledging areas, but the proportions predominantly (>75%) available for development (land use that modifies landscapes) or with 26–50% of total area in choice habitat were larger than post-fledging areas, and half as many nests had >51% of area in choice habitat. Among cover types, choice habitat averaged 39.4% of the post-fledging area. These findings increase uncertainty about conservation measures contributing sufficient habitat to sustain well-distributed, viable populations of northern goshawks throughout Southeast Alaska and demonstrate the need and feasibility of evaluating assumptions of conservation plans.

KEY WORDS *Accipiter gentilis*, conservation strategy, land-use planning, northern goshawk, population viability, southeastern Alaska, temperate rainforest.

Maintaining biological diversity, especially viability of endemic organisms, continues to rank high among land-management issues on public (Possingham et al. 1993, Szaro and Johnston 1996, Iverson and René 1997, Smith and Zollner 2005) and private lands (Lindenmayer and Possingham 1996) because wildlife species are valued by many segments of society (Naess 1986, Catton and Mighetto 1998) and because persistence of indigenous wildlife populations at "ecologically effective" densities (*sensu* Soulé et al. 2003, p. 1,239) is a crucial component of healthy ecosystems (Pimm 1991, Petchey 2000, Pyare and Berger 2003, Soulé et al. 2003). Loss or fragmentation of habitats due to human activity are directly associated with the rapid decay of ecological and evolutionary diversity worldwide (Pereira et al. 2004, Reed 2004). Undoubtedly, global demands for natural resources will continue to increase and land managers will experience greater and more complex challenges to safeguarding ecosystem functions (Costanza et al. 1997, Newton and Freyfogle 2005).

In Southeast Alaska, USA, the Tongass National Forest responded to challenges of sustaining viable and widely distributed wildlife populations across the planning area by developing a comprehensive, regional conservation plan. The 1997 Tongass Land and Resource Management Plan established a system of small, medium, and large reserves to provide large areas of protected, intact old-growth forest and site-specific standards and guidelines to manage locally important habitat for sensitive species (U.S. Forest Service 1997). A fundamental assumption was that lands managed for timber production would contribute little toward maintaining well-distributed and viable populations (U.S. Forest Service 1997: appendix N); rather, reserves and other protected lands would provide sufficient habitat to sustain indigenous wildlife (Iverson and René 1997).

Setting aside essential habitat is a common strategy to maintain indigenous wildlife in modified landscapes, but the underlying assumptions or the effectiveness of such strategies are rarely evaluated (Smith et al. 2011). Although land-use or conservation plans typically stipulate long-term effectiveness monitoring of framework elements and specific measures (U.S. Forest Service 1997: chapter 6), the costs required to do so often are prohibitive, and thus monitoring plans rarely are fully implemented (Patla 2005, Smith et al. 2011). More importantly, irreparable negative impacts can occur before long-term monitoring uncovers flaws in the underlying conceptual framework, or

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in deficiencies in the implementation of specific management guidelines or conservation measures (Smith et al. 2011). However, Smith and Person (2007) demonstrated the feasibility and value of evaluating elements and assumptions of the underlying theoretical framework of a regional conservation plan.

The northern goshawk (*Accipiter gentilis*) in Southeast Alaska received special consideration as a "sensitive species" in the revised forest plan (U.S. Forest Service 1997, pp. 4–89), in part because of concerns over the viability of endemic Queen Charlotte goshawk (*A. g. laingi*) populations (Iverson et al. 1996, Iverson and René 1997, U.S. Fish and Wildlife Service 2007). Standards and guidelines for forest management actions were established using important ecological aspects of this species' biology (Iverson et al. 1996). The 1997 standard and guidelines specific to goshawk reproduction stipulated that managers should "preserve nesting habitat around all confirmed and probable nest sites" (U.S. Forest Service 1997, pp. 4–89) and included several criteria for identifying nest sites and guidance related to achieving this objective.

Much of the science used to develop the Tongass standards and guidelines and policy for managing habitat for northern goshawks was based on studies conducted elsewhere because local information was largely unavailable (Iverson et al. 1996). Since 1997, however, considerable effort has yielded valuable empirical data about the life history, ecology, and habitat needs of northern goshawks in Southeast Alaska, especially during the breeding season (Flatten et al. 2001, Lewis et al. 2006). In addition, there have been numerous studies and reviews completed throughout its range (Penteriani 2002, Andersen et al. 2005, Greenwald et al. 2005, Boal et al. 2006). Moreover, reviews and studies in British Columbia, Canada, have substantially increased our knowledge about goshawks in temperate rainforests (Cooper and Stevens 2000; McClaren et al. 2002, 2003, 2005; Mahon and Doyle 2005, Doyle 2006).

In western North America, the breeding home ranges of northern goshawks often are represented as a hierarchical sequence of 3 areas (Andersen et al. 2005), all of which need to be considered simultaneously in land-use planning or mitigation (Reynolds et al. 2006, Northern Goshawk *Accipiter gentilis laingi* Recovery Team 2008): 1) nest area, 2) post-fledging (family) area, and 3) foraging area. Nest areas provide alternate nest trees, roost trees, prey-plucking posts, and serve as centers of essential breeding behaviors or life-history events (Reynolds et al. 1992, 2006). Post-fledging areas surround active nest trees and represent the core-use area of an adult female and of young goshawks after fledging but before becoming independent of adults and dispersing (Kennedy et al. 1994). McClaren et al. (2005) suggested the biological role of post-fledging areas and nest areas are similar and therefore it is useful to consider them as one functional component. Regardless, the habitat composition (i.e., overstory) of post-fledging areas should be similar to nest areas (Reynolds et al. 2008). Foraging areas comprise the majority of northern goshawk breeding home ranges and are especially important for adults providing food to young and for juveniles prior to natal dispersal. Adults may have foraging areas that are a considerable distance from nests and may change their foraging areas seasonally or from 1 year to the next (Titus et al. 1994). Foraging areas generally are large ($\geq$2,000 ha) but vary among localities and according to individual experience, hunting efficiency, food requirements (brood size), and availability of food within home ranges (Kennedy et al. 1994). Also, the combined home range of male and female pairs can be substantially larger than that of individual birds (Boal et al. 2003). The most imminent threats to breeding populations are loss or fragmentation of nesting and foraging habitat, especially reductions in prey diversity and availability (Reynolds et al. 1992, 2006, 2008; Finn et al. 2002, McGrath et al. 2003, Salafsky et al. 2007, Northern Goshawk *Accipiter gentilis laingi* Recovery Team 2008).

Despite a substantial increase in knowledge since the revision of the 1997 Tongass Land and Resource Management Plan, the implications of those new insights to goshawk conservation and land-use policies in Southeast Alaska have not been rigorously examined. In particular, it is unclear whether a system of old-growth reserves designed explicitly for other wildlife species and protection of goshawk nest trees in landscapes intensively managed for timber (clearcut logging) would provide sufficient habitat to sustain breeding populations of the northern goshawk across the planning area (Finn et al. 2002). The purpose of this study is to evaluate the underlying framework and assumptions of the Tongass conservation strategy to sustain well-distributed, breeding populations of a species whose home range encompasses entire watersheds and whose life history in Southeast Alaska appears to require vast amounts of old-forest habitat (Iverson et al. 1996). To accomplish this, I undertook a spatially explicit analysis that quantified contributions of the 1997 Tongass conservation strategy toward sustaining suitable habitat in 2 essential components of northern goshawk breeding pairs' home ranges: post-fledging area and breeding home range of females. Specific objectives were to 1) use the findings of habitat-use analyses from Southeast Alaska (Iverson et al. 1996) in conjunction with the observed habitat composition of nest sites to identify choice habitat for nest areas; 2) use juvenile post-fledging movements to estimate the radii of circular, virtual post-fledging areas and broader landscapes represented by the median 90% minimum convex polygons breeding home range ("use areas," Iverson et al. 1996) of females; 3) quantify contributions (total acreage) of the Tongass conservation elements to conserving secure (protected from development) habitat in projected goshawk post-fledging area and female breeding home ranges; 4) compare the cover-type composition of virtual post-fledging areas with the observed composition of nest sites in Southeast Alaska and to published recommendations for post-fledging area composition (Reynolds et al. 1992, 2006, 2008); and 5) classify projected northern goshawk post-fledging and breeding home ranges according to the extent (percentage categories) that the habitat composition approached recommended guidelines or the observed percentages of habitat types among nest sites in Southeast Alaska.

STUDY AREA

The Tongass National Forest encompassed about 95% of southeastern Alaska; this included the Alexander Archipelago with thousands of islands, and a narrow mainland region that extended from Dixon Entrance (54°30′N latitude) to the Malaspina Glacier (59°45′N latitude; U.S. Forest Service 1997). The Tongass was unique among national forests in several ways (Everest et al. 1997), including a dynamic geological history, naturally fragmented and isolated landscapes, and extraordinary environmental complexity (MacDonald and Cook 1996).

Southeastern Alaska had glaciated mountain ranges and fjords, and a cool, wet (200- to 600-cm precipitation) maritime climate with mean monthly temperatures ranging from 13° C in July to 1° C in January (Searby 1968). About 4 million ha (60%) was forestland (U.S. Forest Service 1997), of which 2.2 million ha was productive forests (Julin and Caouette 1997). Coniferous rainforest dominated the landscape from shoreline to about 600 m elevation, with approximately 90% of productive forests in Sitka spruce (*Picea sitchensis*)—western hemlock (*Tsuga heterophylla*) forests, which typically are the old-growth forests of upland sites; remaining areas were alpine, muskeg, or riparian (Hutchinson and LaBau 1974). Unmanaged forests typically had a multi-layered overstory of uneven-aged trees, dominant trees that generally were >300 years old, and extensive, structurally diverse understories (Ver Hoef et al. 1988). These forests varied in structure from "scrub" or low-volume communities of short (<10 m), small (<0.5-m diam) trees with open canopies and dense, shrubby understories on poorly drained sites (peatland), to highly productive sites that supported high-volume stands with a closed canopy; tall (>60 m), large (>3-m diam) trees; and a predominantly herbaceous understory (Harris and Farr 1974, Alaback 1982). The *Tsuga–Picea* forest type constitutes most of the closed-canopy forests in the region (Alaback 1982). It was spatially heterogeneous at a fine scale—<1 ha (Schoen et al. 1984)—and typically occurred on low elevation, well-drained sites, frequently as a mosaic with muskegs (Neiland 1971). The primary disturbance was wind, with infrequent (100–200 yr) catastrophic windstorms blowing down tens to hundreds of hectares of old-growth rainforest, which produced relatively homogeneous, naturally regenerated second growth with dense canopies (i.e., wind-originated stands; Nowacki and Kramer 1998). More frequent, but less severe, windstorms blow down one or a few trees, which produces gap-phase old-growth stands with more fine-scale heterogeneity and much larger and older trees (Alaback 1982).

METHODS

Discerning Post-Fledging Area Habitat

I used the 2003 geographic information system (GIS) database of northern goshawk nest-tree locations obtained during 1989–2003 from annual surveys of nests conducted by the Tongass National Forest, Alaska Department of Fish and Game, and U.S. Fish and Wildlife Service (Flatten et al. 2001). Some nests were found by tracking radiocollared goshawks, coincidentally while conducting other fieldwork (e.g., timber sale surveys), or from reports by individuals recreating on the National Forest (Iverson et al. 1996). I updated the 2003 database with new nest trees obtained from surveys conducted through July 2005 by the Tongass National Forest and cooperators. Because many goshawk nests were located during timber-sale surveys or layout (Iverson et al. 1996), the relative amount of high- and medium-volume old growth distributed among land-use designations might have been biased toward the Development category (lands available for timber production and other uses that modify landscapes) as compared with a random sample collected across the region (Daw et al. 1998). However, Schempf et al. (1996) used standardized protocols to survey 724 points within 62 plots across 67 km^2 of roadless areas in Southeast Alaska. They recorded responses from only a single adult goshawk and concluded that the much lower (order of magnitude) detection rate (compared with similar surveys in other portions of this species' range) suggested a low density and widely dispersed goshawk population across the sampling area.

The desired condition of a post-fledging area is habitat composition similar to the nest area (Reynolds et al. 1992, McClaren et al. 2005). Therefore, I identified habitat for post-fledging areas by averaging the composition of cover types (e.g., old-growth forest, muskeg, managed forest) within nest areas of previously occupied nest sites in the region. Post-fledging area habitat was delineated according to the findings of an analysis of habitat selection during the breeding season that compared the proportion of radiotelemetry locations in each habitat type with the proportion that each corresponding habitat type comprised in "use areas" represented by 100% minimum convex polygons (Iverson et al. 1996). During the breeding season, goshawks selected high-volume (forest-wide mean $\pm$ 95% CI $= 201.5 \pm 4.7$ m^3/ha) and medium-volume (146.2 ± 4.5 m^3/ha) strata old-growth forests (Julin and Caouette 1997). Mature sawtimber (75- to 150-yr second growth), low-volume (91.5 ± 4.5 m^3/ha), and scrub forests (<76 m^3/ha) received much less use, which did not differ from that expected according to availability; clearcut (approx. 0–40 yr) and non-forest cover types were avoided. Because nest areas typically are 10- to 12-ha areas immediately surrounding the nest site (Reynolds 1983; Reynolds et al. 1992, 1994), I used a 10.5-ha nest area to accomplish English GIS queries.

To discern available vegetation community types comprising goshawk habitat, I overlaid the location of each nest tree on a 2003 Tongass National Forest data layer of forest stand volume and totaled the area within each polygon that represented a unique volume strata of old-growth forest (low, medium, high). I summed total area of each stratum to determine relative composition of a nest area, centered on the nest tree, and to determine the frequency distribution of nest areas by low-, medium-, or high-volume old-growth forest. Because the vast majority of second-growth was <50 years old (Barbour et al. 2005), mature sawtimber represented a very small (approx. 1%) component of the forested landscape. Scrub forests are peatlands with little or no forest canopy (Harris and Farr 1974). None of the 136 nests were in sawtimber or scrub forests. Therefore, I assumed that medium- or high-volume old-growth forests provided the resources needed by northern goshawks during the breeding season based on the previous findings of habitat selection (Iverson et al. 1996) and because nest trees were invariably in medium- or high-volume old-growth stands.

Composition of Virtual Areas

To determine contributions of the Tongass conservation strategy toward meeting breeding-season habitat objectives, I estimated the size of a post-fledging area in Southeast Alaska according to concepts in Kennedy et al. (1994), the behavior of post-fledged juveniles (Kenward et al. 1993), and published data on juvenile movements during the post-fledging period (Iverson et al. 1996). I used 1,600 m to estimate the average limit of all movements of post-fledged juveniles because this was assumed to be the distance that defined when juveniles were undertaking post-fledging movements (Kenward et al. 1993) and because 23 of 28 juvenile goshawks monitored with radiotelemetry in Southeast Alaska moved ≥1,600 m (Iverson et al. 1996). I then used this estimate of distance moved during the post-fledging period as the radius of circular areas centered on a nest to represent an "average post-fledging area." I used the median home range (90% mononuclear probability polygon; Iverson et al. 1996) of adult females during the breeding season (21 km^2) to delineate broader landscapes that comprised essential foraging habitat (Reynolds et al. 1992, 2006, 2008). Because goshawk males typically do most of the hunting during the nesting period (Kenward 1982), this approach assumes that the male's breeding-season range, which averaged about 50% larger than females, did not differ substantially in habitat composition. I overlaid each nest's virtual post-fledging area and breeding home range on GIS layers of cover types and land-use designations based on stand volume and management history. The area within each polygon that represented a unique land-use description was summed to determine relative composition of 4 land-use categories: Development—lands available for timber production and other uses that modify landscapes; Non-National Forest lands; Natural Setting—lands that maintain a natural setting, such as wild and scenic rivers and remote recreational areas; and Old Growth—protected old-growth forests. The same procedure was used to determine composition of 4 cover types: Habitat—high or medium-volume old-growth forests; Low—low-volume old-growth forests; Clearcut—all lands harvested between 1954 and 2005; Non-forest—all lands that do not support productive forests (Julin and Caouette 1997). The extent to which the female home range and post-fledging area differed in composition served as a metric of landscape heterogeneity that also provided insights about the sensitivity of this analysis to sampling error and the likelihood that habitat composition of male breeding ranges differed from females. Results are presented as separate summaries of average land-use designation or cover-type composition for post-fledging areas and seasonal home ranges.

RESULTS

Nest Area and Habitat

I determined habitat used by goshawks for the post-fledging area analysis using the habitat composition of 136 nest areas across the Tongass National Forest: overall, 100% of the nest trees were in productive (low-, medium-, or high-volume) old-growth forests, which comprised 66.1% (SD = 0.05) of goshawk nest areas. The remainder of nest areas was in scrub forests (fens), non-forested areas (muskegs), or regeneration stands following clearcut logging. A total of 58 nest areas primarily (>50%) consisted of high-volume old growth; 57 and 15 nest areas primarily consisted of medium- and low-volume old growth, respectively. Six nest areas did not contain any old-growth forest; according to notes in the database file, those nest trees were located in portions of the forest that were clearcut-logged after a breeding pair had selected a nest tree. If nest trees on clearcut sites or near a natural feature creating an abrupt forest edge (e.g., shoreline) were excluded ($n = 11$), mean proportion of productive old-growth forest in nest areas was 0.712 (SD = 0.041). The mean proportions of volume strata in the remaining nest areas ($n = 125$) were 0.097 (SD = 0.025), 0.283 (SD = 0.039), and 0.289 (SD = 0.039) for low-, medium-, and high-volume forests, respectively. Based on the habitat at 125 nest sites and within corresponding nest areas and on the findings of a previous habitat selection study (Iverson et al. 1996), I refer to medium- or high-volume old growth in virtual areas below as "choice habitat."

Land-Use Designation and Habitat Composition of Virtual Areas

The composition of land-use designations of an average post-fledging area contained a relatively large proportion of Development (land uses that modify landscapes) lands, with >30% of all nest areas having >91% of the post-fledging area as lands available for timber production (Fig. 1a; Appendix A). Cover-type composition of post-fledging areas contained a relatively large proportion of non-forest cover types (Fig. 1b). About 30% of the nests had >51% (i.e., 51–75%, 76–90%, or >90%) of the corresponding post-fledging area in medium- or high-volume old growth (choice habitat); 51% of nests had 26–50% of the post-fledging area in choice habitat. Most (60%) of this choice habitat was in the Development land-use designation or Non-National Forest designation (Fig. 1a); 16% of the nests had >51% of the post-fledging area in the Old-Growth land-use designation, with the remainder in Natural Setting. Across all nest areas, the Old-Growth land-use designation averaged 14.8% (100 ha; SE = 4.6) of the total post-fledging area acreage. Development, Non-National Forest, and Natural Setting averaged 41.1% (278 ha; SE = 7.6), 13.5% (91 ha; SE = 4.6), and 27.2% (184 ha; SE = 6.9), respectively. Among cover types, choice habitat averaged 39.4%

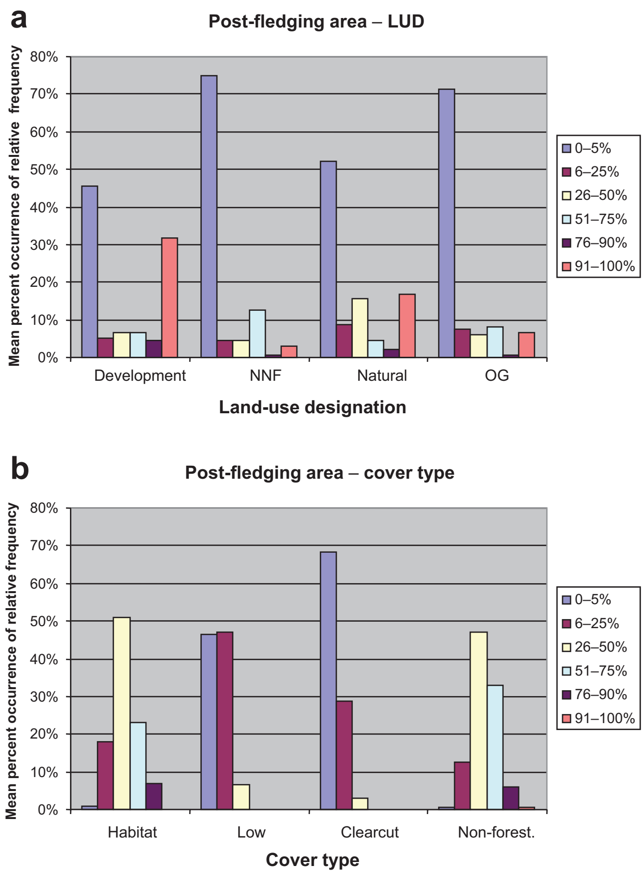

Figure 1. Mean percent occurrence of relative frequency (%) categories of land-use designations (a) and cover types (b) in 136 virtual northern goshawk (*Accipiter gentilis*) post-fledging areas (800 ha) in Southeast Alaska, USA. Total area was calculated from an estimate of the average post-fledgling movements (1,600 m), which served as radius of a circular area. Development = lands available for timber production and other uses that modify landscapes; NNF = non–national forestlands; Natural = lands that maintain a natural setting, such as wild and scenic rivers and remote recreational areas; and OG = protected old-growth forests. Cover types: Habitat = high- or medium-volume old-growth forests; Low = low-volume old-growth forests; clearcut = all lands harvested between 1954 and 2005; Non-forest = all lands that do not support productive forests (Julin and Caouette 1997).

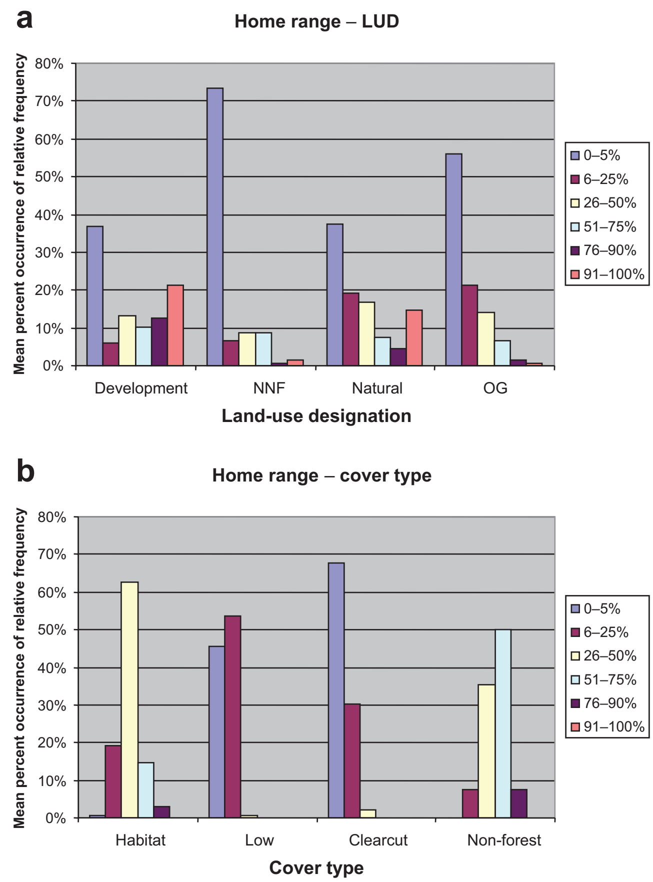

Figure 2. Mean percent occurrence of relative frequency (%) categories of land-use designations (a) and cover types (b) in virtual female breeding home ranges (2,100 ha) encircling 136 northern goshawk (*Accipiter gentilis*) nest sites in Southeast Alaska, USA. Total area was calculated from an estimate of goshawk movements (2,600 m), which served as radius of a circular area. Land-use designations: Development = lands available for timber production and other uses that modify landscapes; NNF = Non-National Forest Lands; Natural = lands that maintain a natural setting, such as wild and scenic rivers and remote recreational areas; and OG = protected old-growth forests. Cover types: Habitat = high- or medium-volume old-growth forests; Low = low-volume old-growth forests; clearcut = all lands harvested between 1954 and 2005; Non-forest = all lands that do not support forests (Julin and Caouette 1997).

(266 ha; SE = 9.3) of the post-fledging area; low volume forest, clearcut, and non-forest lands averaged 8.3% (56 ha; SE = 2.6), 3.9% (27 ha; SE = 1.5), and 45.0% (304 ha; SE = 10.3), respectively.

Similar results were obtained from an analysis of the female breeding home range, but with 3 notable differences. The percentage of this broader landscape that consisted predominantly (>75%) of lands available for development was greater than in post-fledging areas (Fig. 2a; Appendix A). The percentage of the total area with 26–50% of the total area in choice habitat also increased in comparison with the post-fledging area, whereas about half as many nests had ≥51% of this broader landscape in choice habitat as compared with the post-fledging area (Fig. 2b).

DISCUSSION

The 1997 Tongass Land and Resource Management Plan included multiple conservation measures to maintain habitat, with a goal of sustaining viable and widely distributed populations of indigenous wildlife throughout the planning area. Although some elements of the 1997 Tongass Land and Resource Management Plan have undergone revision, the wildlife conservation strategy remains largely unchanged (Smith et al. 2011). Individual species, such as the northern goshawk, received specific conservation measures to reduce viability risks (Iverson et al. 1996). According to the conservation assessment, implementation of the 1997 Tongass Land and Resource Management Plan for 100 years would result in “a moderately high likelihood of providing the amount and distribution of habitats to sustain long-term well distributed viable populations of goshawks throughout the Tongass” (U.S. Forest Service 1997: appendix N38). This long-term projection, an inherent assumption of the conservation strategy, was based on analyses at multiple spatial scales (U.S. Forest Service 1997). This study used contributions of various elements of the conservation strategy to biological components of the breeding range centered on specific nest sites. This approach allowed an examination of the underlying assumption that the 1997 Tongass Land and Resource Management Plan provides habitat needed to sustain breeding populations of goshawks across the planning area. Productive old-growth forests unavailable for timber harvest were used frequently by northern goshawks and "thus the contribution of these habitats must be included in an assessment of overall risk to sustainability of goshawk habitat" (U.S. Forest Service 1997: appendix N38).

Standards and guidelines prescribed for protection of goshawk nest areas (40 ha) in Southeast Alaska are unlikely to meet breeding-season habitat objectives established for goshawk populations elsewhere (Reynolds et al. 1992, McClaren et al. 2005). The expectation that, in landscapes managed intensively for timber products, habitat contributed by other elements of the Tongass conservation strategy (e.g., old-growth reserves) will mitigate this deficiency was not supported by my analysis. An ideal northern goshawk home range consists entirely of older forests with small, dispersed openings (Reynolds et al. 2006, 2008). Guidelines for the composition of post-fledging areas stipulate that "the majority (60%)" of a post-fledging area should be in forest of older age classes (Reynolds et al. 1992, p. 23), which continues to be corroborated by further study in other portions of this species' range (Daw and DeStefano 2001), including temperate rainforests (McClaren et al. 2005). In my study, nest areas averaged 71% productive old growth; 58% of the nest area consisted of medium- or high-volume old growth. Before logging, landscapes across Southeast Alaska likely were similar in composition to current nest areas (U.S. Forest Service 1997). At the time of my study, only about one-third of 136 virtual post-fledging areas contained >51% choice habitat. More importantly, the average composition of "unsecure" (i.e., Development or Non-National Forest land-use designations) habitat was 55%, and 60% of all post-fledging areas consisted of >51% unsecure habitat. Regardless of whether I compare these results with guidelines from the southwestern United States or the habitat at nest sites and in nest areas of Southeast Alaska (i.e., desired future condition of goshawk post-fledging areas; Reynolds et al. 2008), the observed composition of post-fledging areas was less than the minimum recommended or desired amount of habitat.

This conclusion differs from a general forest-wide habitat availability assessment (i.e., not linked to specific goshawk nest sites) based on analyses at multiple spatial scales (U.S. Forest Service 1997: appendix N43). I believe the disparity can be explained by differences in scale and biological relevance (i.e., linked to specific life-history needs; Reynolds et al. 2006) of analyses between this study and previous analyses (Iverson et al. 1996, U.S. Forest Service 1997: appendix N38). Some of the analyses cited in the summary appraisal were at a regional scale (forest-wide) and spatially neutral. For example, the conclusion that 95% of the northern goshawk range in the region has a high likelihood of sustaining habitat because 93% of the forests would have <47% of productive old-growth harvested over the planning horizon provides little spatially explicit information about breeding-season habitat, especially for populations occurring on islands. Also, results of stand-level analyses cited in the summary largely focused on aspects of forest management that were not immediately relevant to the life-history needs of breeding pairs. Conclusions that only a small percentage of nest areas examined had experienced any logging or that only a small proportion of nest areas were harvested says little about breeding-season habitat or resources available to breeding pairs, especially across the broader landscape. Intermediate-scale analyses and protective measures, such as limiting total harvest to ≤33% of a watershed during the planning horizon (effectively a 300-yr rotation), are spatially explicit and potentially have biological relevance (i.e., approximate size of goshawk home ranges). However, management guidelines not explicitly coupled to northern goshawk breeding ranges or life history are at risk of not meeting habitat needs of individual breeding pairs (Reynolds et al. 2006, Northern Goshawk *Accipiter gentilis laingi* Recovery Team 2008).

At the time of the summary assessment (U.S. Forest Service 1997), about 5% (35/678) of the watersheds exceeded the stipulated threshold of total harvest, with 33–47% of the total available productive old-growth forests already harvested; 26 of those (74%) were concentrated in one Biogeographic Province (North Prince of Wales Island). The assessment acknowledged the higher risks of exceeding watershed thresholds of total harvest, especially across North Prince of Wales Island, but assumed that large reserves in those landscapes would mitigate the habitat loss from excessive timber harvest. The findings of this study suggest that contributions of old-growth reserves and other conservation elements (e.g., riparian or shoreline buffers) might not mitigate the cumulative habitat loss in intensively managed landscapes. This conclusion is supported by evidence on nearby islands that extensive loss and fragmentation of habitat from clearcut logging contributed to population declines of Queen Charlotte goshawks (Doyle 2006).

The threshold composition of suitable habitat to ensure successful breeding by goshawks in Southeast Alaska is unknown. To gain this knowledge requires extensive monitoring and research that chronicles reproductive histories of individual breeding pairs and links fitness to nesting habitat condition (Patla 2005, Reynolds et al. 2005, Salafsky et al. 2007). Still, the findings of this study increase uncertainty that northern goshawk breeding-season habitat objectives are being met in managed landscapes of Southeast Alaska. Two lines of reasoning support this conclusion.

First, spatially explicit analyses of contributions to northern goshawk breeding-season habitat revealed that conservation measures of the Tongass Land and Resource Management Plan contribute about half the secure habitat recommended for post-fledging areas of breeding pairs in the southern portion of this species range (Reynolds et al. 1992) and was less than half the relative amount of habitat documented in nest areas in Southeast Alaska. A similar conclusion was obtained for the broader landscape (21 km^2) that surrounded each nest. This is because much of the habitat across the landscape has been clearcut-logged and half the remaining choice habitat is in the Development land-use designation available for timber harvest. The potential for second-growth stands to become useable habitat (mature sawtimber) over the Tongass planning horizon is limited because unmanaged second growth typically requires ≥300 years following disturbance to develop old-forest features (Nowacki and Kramer 1998). Active management can hasten the development of old-forest condition, but pre- and commercial thinning has occurred in only about 30% of 267,000 ha that have been harvested across the region (Barbour et al. 2005).

Secondly, guidelines developed for northern goshawk populations in the southwestern United States may underestimate habitat needed by breeding pairs in Southeast Alaska. A critical consideration in conserving habitat to support breeding populations is sufficient habitat to sustain prey resources (Reynolds et al. 2006; Salafsky et al. 2005, 2007). Despite possible differences in life history or ecology across the range of northern goshawks, the nesting and foraging habitat of successful breeding pairs must support adequate prey populations. In Southeast Alaska, the predominant (frequency and biomass) prey items during the breeding season (Lewis et al. 2006) are bird and mammal species that are most abundant, or occur exclusively, in productive old-growth forests (Iverson et al. 1996, Russell 1999; Smith et al. 2001, 2004, 2005). Consider further that the mammal fauna of Southeast Alaska is depauperate (MacDonald and Cook 1996); few mammal species exclusively occur in low-volume or managed forests of Southeast Alaska (Smith et al. 2001, Smith and Nichols 2004); and the structure of dense second-growth stands effectively renders prey unavailable to foraging goshawks (Beier and Drennan 1997). Avian communities in managed forests include few, if any, additional prey for northern goshawks (Smith et al. 2001). Thus, breeding pairs in managed landscapes of Southeast Alaska likely rely almost entirely on productive old-growth forests as foraging and nesting habitat. That breeding pairs in managed landscapes of Southeast Alaska depend on productive old-growth forests to meet life-history needs was reflected in the findings of compositional analyses and radiotelemetry studies, both of which determined that northern goshawks strongly selected medium- and high-volume old-growth forests and avoided recently managed or non-forested habitats (Iverson et al. 1996).

PLANNING AND MANAGEMENT IMPLICATIONS

Management guidelines for northern goshawks in the southwestern United States recommend active management of the entire planning area to regenerate forests as well as provide nesting and foraging habitat. Despite insufficient local information to prescribe the design of a reserve-based approach to sustain northern goshawks, a hierarchical system of habitat reserves became the cornerstone of the TLMP wildlife conservation strategy to sustain viable and well-distributed populations across Southeast Alaska. This was to a large part a result of having to consider the risk to viability of multiple species for which there was more theoretical or empirical evidence that habitat reserves would sustain viable populations. Because additional conservation measures were incorporated at multiple spatial scales in the 1997 TLMP to provide sufficient nesting and foraging habitat for northern goshawks, the conservation strategy for northern goshawks in southeastern Alaska became a composite of conservation measures superimposed on a conceptual framework developed for other vertebrate species of concern.

More importantly, the 1997 TLMP did not incorporate the concepts of nest area, post-fledging area, and foraging area habitat management that underpin the current paradigm of conservation planning to sustain viable populations of northern goshawks across a significant portion of its range. However, applying these concepts to temperate rainforests and to a planning area that differs markedly in natural history, forest type, landscape structure, and management history requires a thorough understanding of differences and similarities in goshawk behavior and ecology among regions. Still, managing for uncertainty and avoiding the risk of trending the population downward can be improved by using biological concepts applied elsewhere to sustain northern goshawk habitat and populations throughout southeastern Alaska. The nuances of local ecological variability and subsequent refinement of management guidelines can be uncovered with additional field study. Meanwhile, biologists and land managers may want to consider ecological consequences to northern goshawk populations (and associated ecological communities) of potential habitat deficiencies in managed landscapes across the region. Planners and managers may want to revisit assumptions that current standards and guidelines and other conservation measures provide sufficient breeding season habitat to sustain viable and widely distributed goshawk populations. In the interim, project planning and land use management can be used to increase the longer-term security of preferred habitat (e.g., deferred harvest) or improve (e.g., thinning) marginal or unsuitable habitat in managed landscapes, especially across the North Prince of Wales Island Biogeographic Province.

Conservation plans rely on setting aside essential habitat to assure viability of indigenous wildlife communities in intensively developed landscapes. More often than not, little local information exists upon which to develop a sound conceptual framework or identify effective conservation measures. Thus, land-use planning frequently relies on biological data from other regions or incorporates multiple assumptions, many of which lack an underlying empirical or theoretical foundation. Determining the effectiveness of a conservation strategy is a daunting task, requiring long-term habitat and wildlife population monitoring. However, shorter term evaluations are possible and desirable to scrutinize underlying assumptions, identify deficiencies, refine elements and procedures, and prevent irreparable negative effects, should a conservation plan depend on long-term monitoring.

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Appendix A. Percentage of relative frequency (%) classes of 4 land-use designations (LUD) and 4 cover types in 2 types of ecological areas encircling 136 northern goshawk (*Accipiter gentilis*) nest sites in Southeast Alaska, USA. The radius of the post-fledging area (PFA) is based on the average movement (1,600 m) and the radius of the broader landscape is based on the average use area (90% mononuclear probability polygon) of radiocollared adult female goshawks during the breeding season (Iverson et al. 1996).

Ecological areas	**LUD composition (%)**				**Cover-type composition (%)**			
Percentage categories	**Development**	**NNF**	**Natural**	**OG**	**Habitat**[a]	**Low-volume old growth**	**Clearcut**	**Nonproductive forest**
PFA								
0–5	46	75	52	71	1	46	68	1
6–25	5	4	9	7	18	47	29	13
26–50	7	4	15	6	51	7	3	47
51–75	7	13	4	8	23	0	0	33
76–90	4	1	2	1	7	0	0	6
>90	32	3	17	7	0	0	0	1
Total	100	100	100	100	100	100	100	100
Home range								
0–5	37	74	38	56	1	46	68	0
6–25	6	7	19	21	19	54	30	7
26–50	13	9	17	14	63	1	2	35
51–75	10	9	7	7	15	0	0	50
76–90	13	1	4	1	3	0	0	7
>90	21	1	15	1	0	0	0	0
Total	100	100	100	100	100	100	100	100

[a] Medium- or high-volume strata old-growth rainforest (Iverson et al. 1996).